

Physics 330 – Problem Set # 9

(due Wednesday, December 7)

1. This problem concerns non-standard corrections to the electron and muon ($g - 2$).

- (a) Consider adding to QED a new neutral scalar boson ϕ with mass M and a coupling to the electron and the muon of the form

$$\Delta\mathcal{H} = \lambda\phi\bar{\psi}\psi . \quad (1)$$

Compute the contribution to the lepton ($g - 2$) from the 1-loop diagram that involves this boson.

- (b) Alternatively, consider adding to QED a new neutral pseudoscalar boson χ with mass M and a coupling to the electron and the muon of the form

$$\Delta\mathcal{H} = i\lambda\chi\bar{\psi}\gamma^5\psi . \quad (2)$$

Compute the contribution to the lepton ($g - 2$) from the 1-loop diagram that involves this boson.

- (c) At the moment, there seems to be an anomaly in the muon ($g - 2$), such that a contribution is needed from sources outside the known interactions of particle physics, to give a correction

$$\Delta\left(\frac{g-2}{2}\right) \approx +2 \times 10^{-9} . \quad (3)$$

[Caution: This is, at best, a 2.5σ effect.] In each of the two models above, compute the condition on M and $\alpha_\lambda = \lambda^2/4\pi$ to give an effect of this size.

- (d) For the electron ($g - 2$), there is spectacular agreement between theory and experiment:

$$\left| \Delta\left(\frac{g-2}{2}\right) \right| < 5 \times 10^{-11} . \quad (4)$$

This includes the uncertainty in α , which must be determined in another high-precision experiment, for example, the measurement of the quantum unit of resistance in the quantum Hall effect. Are the models of the anomaly in the muon ($g - 2$) that you considered in part (c) consistent with this constraint?